RESULTS OF INVESTIGATION OF MUON FLUXES OF SUPERHIGH ENERGY COSMIC RAYS WITH X-RAY EMULSION CHAMBERS

Ivanenko I.P., Ivanova M.A., Kuzmichev L.A., Ilyina N.P., Mandritskaya K.V., Osipova E.A., Rakobolskaya I.V.
Institute of Nuclear Physics, Moscow State University, Moscow 119899, USSR

Zatsepin G.T., Institute of Nuclear Investigation, Academy of Sciences of the USSR, Moscow

The paper presents the overall data of investigation of the cosmic ray muon flux in the range of zenith angles (0-90)° within the energy range (3.0-5 0) TeV. The exposure of large X-ray emulsion chambers underground was 1200 tonn. year.

The data were processe using the method which has been applied in the experiment "Pamir" and differred from the earlier applied one. The obtained value of a slope power index of the differential energy spectrum of the global muon flux is =3.7 that corresponds to the slope of the pion generation differential spectrum, $\gamma_\pi = 2.75 \pm .04$.

The analysis of the muon zenith-angular distribution showed that the contribution of rapid generation muons in the total muon flux agree the best with the value .2% and less with .7% at a 90% reliability level.

In Moscow State University a large array of 140 X-ray emulsion chambers comprising the total of 250 tonn of lead and 5000 m^2 of X-ray film was esposed during 10 years from 1970. The goal of the exposure was to determine the energy and zenith-angular distributions of high-energy cosmic ray muons. The array was located at 5-6 meters underground, the chamber planes forming angles of 45° and 60° with the horizon and providing a similar registration of the vertical and horizontal fluxes.

During the exposure the results on 400 chambers that is equal to 1200 tonn-year were obtained. The total efficiency of the array is $2.4 \cdot 10^{17}$ g·s·ster.

The methodical aspects of the experiment and the result of processing the data have been reported at several International Cosmic Ray Conferences /1,2,3/.

At the Conference in Paris/3/, we reported on the spectra and zenith-angular distribution obtained using a bulk of statistical material.

A power index of the differential energy spectrum of the global muon flux in the energy range (3-30) TeV was equal to $2.92 \pm .07$. The processes of rapid generation of muons with energy (3-13) TeV in the nuclear interaction was estimated as (.1-.2)%.

Lately we investigated experimental fluctuations in the electron-photon cascade development in a chamber and

calibrated the methods of cascade energy determination/4/. Errors in the energy determination were shown to be somewhat larger than expected ones and the mass of π^0-meson determined by a calibration installation at the Pamirs used in earlier muon papers was shown to be underestimated. Comparison of the methods applied when processing the Pamirs and muon chambers, indicated that different approaches to allowance for the diffuse light in photometering and somewhat different optical density curves may lead to a change in the energy spectrum slopes by $\Delta\gamma = .10-.15$.

In connection with the above consideration, the total bank of experimental data from the muon chambers was processed using the procedure of going over from optical density to energy accepted in the Pamir Collaboration. The bank was simultaneously processed by the earlier method allowing more correct regarding of experimental bais and installation apparatus.*

The total of 7000 electron-photon cascades with energy higher than 2 TeV were detected. Thus, we measured the energy spectrum of bremsstrahlung gamma-rays in the range of zenith angles 0°-90° and, proceeding from this spectrum and regarding chamber efficiency, measurement fluctuations and muon zenith-angular distribution, we found the vertical muon flux spectrum in the energy range 3.0-50 TeV(In the last interval from 32 to 50 TeV 9 muons and one muon with energy $\sim$ 130 TeV were registered).

The slope power index of a differential spectrum of the global flux of electron-photon cascades proved to be $3.72\pm .04$. Its value corrected for electromagnetic and experimental fluctuations was $\gamma_{EPC}=3.61\pm.04$. The errors shown are statistical ones.

For the global flux of cosmic ray muons a power index was found to be $\gamma=3.7$, and after going over to the vertical it was obtained to be $\gamma=3.75\pm.04$. The latter value corresponds to the power index of the pion generation differential spectrum, $\gamma_\pi=2.75\pm.04$.

After processing the data bank by the earlier used method proved to be $2.86\pm.05$ that is by a factor of .15 less than the value in /3/.

Fig.1 shows the data of various papers on investigation of the energy spectra of cosmic ray muons in various energy ranges. Our latest data are in good agreement with conclusion made by the authors of "Mutron"/5/ and conclusions of the authors of /6/(the underground array in Artemovsk).

Thus, at high energies the muon spectrum is steeper by some 3.65-3.75, if steepening is observed at all, that may be caused by a small variation of a power index of the primary nucleon spectrum or by a weak scaling violation

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* The bank was processed by N.Ilyina using the Pamirs method, and by E.Osipova using the earlier used method

in the fragmentation region(in the nucleon energy range from 16 TeV to 200-300 TeV).

The contribution of rapid generation muons into the total muon flux was also analysed. Fig.2 presents the ratios of the number of cascades from the horizontal muon flux($\theta > 66°$) to that from the vertical flux ($\theta < 66°$) as a function of muon energy. Analysed were all cascades with energy higher than 3.0 TeV(muon energy ~ 4 TeV).

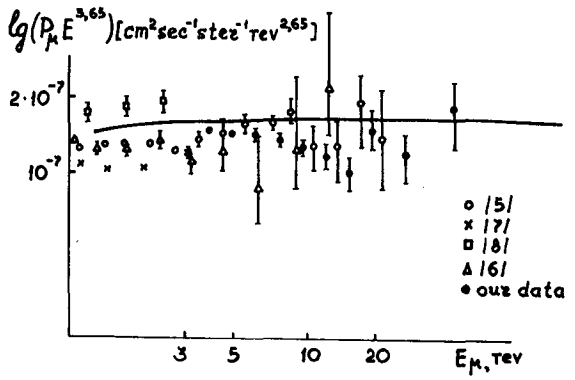

Fig.1. Intensities of the muon vertical flux obtained in various papers. The solid line is for calculations of the muon flux intensity from /10/.

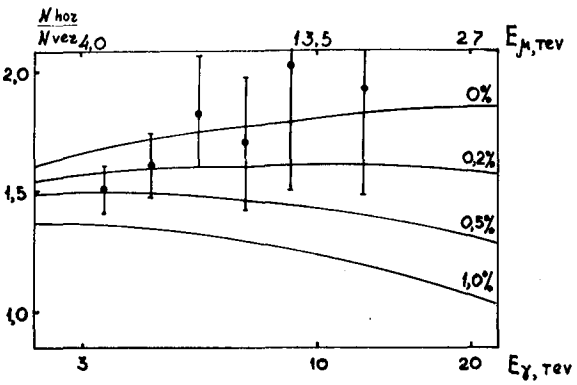

Fig.2.The ratio of the number of cascades from the vertical muon flux versus cascade energy

The solid curves show the expected flux ratios at various values of fast muon fractions, R(R denotes the ratio of inclusive cross sections of production of fast muons to that of pions averaged with respect to the primary cosmic ray spectrum), the kaon content being assumed of 15%. The χ^2-test performed to estimate R showed the best agreement of experimental data at R = .2%. R = .7% with a 90% reliability. The results obtained are consistent with our earlier conclusions /3/ and show R to be unsensitive to methodical corrections of our experiment. The data also agree with contemporary theoretical estimates of cross sections of charmed particle production.

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